# Impacts of Future US GHG Regulatory Policies on Large-Scale Coal to Liquids Plants

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#### **Abstract**

Mandatory US regulation of greenhouse gas (GHG) emissions could strongly impact the design and financial return of future US coal-to-liquids (CTL) projects due to the size of their carbon footprint. This paper presents the results of a Department of Energy (DOE) sponsored analysis examining the impact that future carbon prices could have on a nominal 50,000 barrel per day (BPD) Illinois CTL plant.

The first phase of the paper presents the results of two CTL plant designs: one with and one without carbon sequestration. Basic information on the plant layouts, performance, cost, carbon emissions, financial results (without placing a value on CO<sub>2</sub>), and major sensitivities provides the basis for subsequent analysis.

The second phase discusses the major CO<sub>2</sub> regulatory policies being evaluated in the 110<sup>th</sup> Congress, and how these policies, by placing a value on CO<sub>2</sub>, could impact the financial performance of CTL plants. Two different methods are undertaken for estimating CO<sub>2</sub> cost: a range of flat prices throughout the life of each project, and a ramp-up of CO<sub>2</sub> price during the performance period, reflecting the potential for tighter emissions regulations in 2020 and beyond. These costs are entered into the base case financial models for each CTL plant design.

The results show the expected return on investment for each project under a range of CO<sub>2</sub> price scenarios, and what CO<sub>2</sub> price(s) would be necessary to economically justify the sequestration of CO<sub>2</sub>. Preliminary results at a \$0/ton value for CO<sub>2</sub> show an ROI for the CTL plant without capture at 15.3% and an ROI of 12.0% once compression and sequestration is included. A flat CO<sub>2</sub> price of \$12.50/ton throughout the life of the plant would be required to justify the additional expenditure on the CTL plant with capture. In the alternate CO<sub>2</sub> price scenario, a government target to stabilize CO<sub>2</sub> concentrations at 550 ppm or lower would be necessary to provide a sufficient economic driver for CO<sub>2</sub> capture from CTL plants. Of the 5 major CO<sub>2</sub> reduction policies being considered in the US Senate as of April 2007, only one, Sanders-Boxer, would provide a clear price signal to support CTL plants with carbon capture and storage.

This information is relevant to a complete understanding for how CO<sub>2</sub> regulations could impact this emerging US industry. Project developers considering CTL plants today will likely want to consider including the necessary technology for CO<sub>2</sub> capture and compression since the marginal cost is small relative to other large fossil fuel plants.

# **Introduction**

CTL plants being considered today face the same design dilemmas as coal-fired power plants when it comes to GHG controls. Developers face a major choice that will impact siting and design decisions: whether or not CO<sub>2</sub> produced during the process should be sequestered. Evaluating the cost of including sequestration and comparing it to costs that may be imposed by GHG control policies provides insight into what future federal policy drivers may exist. Projects will also need to take into account state and local conditions that may influence their decision.

This paper first presents the design and financial results of a nominal 50,000 BPD CTL plant both with and without CO<sub>2</sub> sequestration at a \$0/ton CO<sub>2</sub> value. Different methods of CO<sub>2</sub> quantification are then applied to each case to determine which policies may provide sufficient economic drivers to promote sequestration in CTL plants.

## **CTL Plant Design**

The plant design evaluated in this feasibility study incorporates coal gasification technology and a slurry-bed Fischer-Tropsch (F-T) reactor system using an iron-based catalyst. The concept includes a cluster of four gasification plants, each containing two gasifier trains for a total of eight gasifiers. Clean syngas from the gasification plants is sent to a central CTL plant. The CTL plant contains F-T reactors, hydrotreating and hydroisomerization units capable of producing 49,433 barrels per stream day of a liquid syncrude type material that needs to be sent offsite for upgrading into commercial products. The CTL plant also generates electric power, both for internal use and for export to the grid. The base case plant design includes equipment to separate and

compress carbon dioxide to 2,200 psia for pipeline transport. Subsequent off-site use, capture, and/or sequestration of the carbon dioxide are not considered in the base design, although later financial analysis includes cost estimates for transport and sequestration.

Figure 1 provides a simplified block flow diagram of the F-T plant. The analysis is based on Illinois No. 6 bituminous coal and ConocoPhillips' E-Gas<sup>TM</sup> gasification technology. The gasifiers feature a two-stage, oxygen-blown, entrained flow, refractory-lined gasifier vessel with continuous slag removal. Dedicated air separation units supply 95 mole% oxygen to the gasifiers. Syngas leaving the gasifiers is cooled in fire tube syngas coolers, producing high-pressure steam, and then goes to water scrubbers to remove particulates and trace components. The resulting syngas stream is reheated and sent to a packed bed hydrolysis reactor, in which carbonyl sulfide (COS) and hydrogen cyanide (HCN) is converted to hydrogen sulfide (H<sub>2</sub>S). The syngas stream is cooled and sent to a mercury removal system, consisting of packed beds of sulfur impregnated activated carbon, removing mercury, arsenic and other trace materials from the syngas stream. Dual-stage Selexol units sequentially remove H<sub>2</sub>S and CO<sub>2</sub> from the cool, particulate-free syngas stream.

The clean syngas is then sent to the F-T slurry reactor system to produce liquid product. A recycle system is used to maximize liquids production. Carbon dioxide is removed from the unconverted vapors leaving the F-T reactors to minimize the size of the recycle loop and maintain the appropriate ratio of  $H_2$  to  $CO + CO_2$ .

The off-gas from the F-T process is compressed and used as fuel for the GE PG9251FB gas turbine. Hot flue gas from the gas turbine passes through a heat recovery steam generator to produce superheated high-pressure steam. The resulting steam is combined with steam produced by cooling the syngas in the gasification train and with steam generated by recovering heat from the F-T reactors to generate additional electricity. Auxiliary plant loads consume the majority of the generated power, leaving a net 23.7 MWe available for export to the grid when the maximum amount of  $CO_2$  is captured and compressed.

The F-T naphtha fraction is hydrotreated for stability. The heavier F-T hydrocarbons are sent to a hydroisomerization unit. The products from both units are combined to form a pumpable liquid (syncrude) that is sent offsite for further upgrading into finished products. Total plant performance data with maximum  $CO_2$  compression is summarized in Table 1.

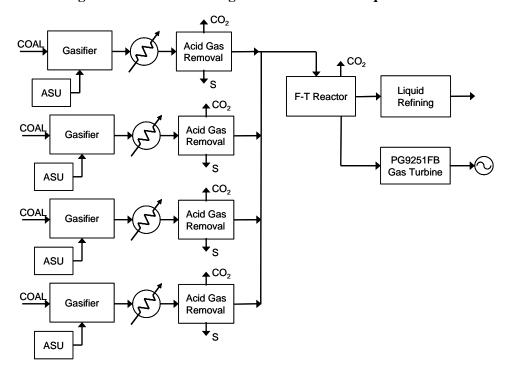


Figure 1 Block Flow Diagram of the Coal-to-Liquids Plant

Table 1 Plant Performance Summary with Maximum CO<sub>2</sub> Compression

Parameter	Value
Coal Feed Flow Rate, tons/day	24,533
F-T Liquids Production (Syncrude)	49,433
Net Plant Power (max CO <sub>2</sub> compression), MW <sub>e</sub>	23.7
Elemental Sulfur Production, tons/day	612
Carbon Dioxide Compression, tons/day	32,406

# **Financial Results**

The results of the plant design and cost estimates for the syncrude plant are used as the basis for the financial analysis. The amount of  $CO_2$  and power export shown in Table 1 represents the maximum amount of  $CO_2$  compression of the cases examined; other sensitivity cases, as outlined below, explore the impact of decreasing this level of capture and compression on the plant financial results.

The key results desired from the analysis are the project return on equity investment, discounted cash flow, and identification of key model sensitivities. Important sensitivities include varying the syncrude value to show the financial results from a number of potential price scenarios and changing the amount of CO<sub>2</sub> compressed to pipeline pressure. The model used to perform this work is the Nexant-developed Power Systems Financial Model (PSFM), Version 5.0.5. This model was originally developed in May 2002 and has since been modified to incorporate additional functionality. The model has been used in numerous gasification studies, and is now the standard used by NETL for gasification project financial analysis. It is a robust discounted cash flow model that takes into account all major financial and design assumptions in developing the outputs.

The plant EPC cost entered into the financial model is taken from the team analysis based on past studies and best available current information. "Bare Erected Cost" is combined with the engineering and home office fees to produce the EPC cost. On top of these costs, a ~26% project contingency, 25% process contingency on the F-T synthesis section of the plant, 2% start-up cost, and 10% owner's cost is included to reflect the total costs. These additional costs increase the "Total Project Cost" to \$4.37 billion. The results of the financial analysis can be seen in Table 2 below:

**Table 2** Financial Model Results

Major Inputs		
EPC Cost (\$MM)	2,722	
Syncrude Production (BPD)	49,433	
Coal Feed Rate (TPD)	24,533	
Major Results		
ROI (%)	14.4	
NPV (\$MM, 12%)	438	
Payback Period (Yrs)	8	
Crude Oil Price for 12% ROI (\$/Bbl)	55	

The base case result shows positive financial performance, with a 14.4% return on equity investment and a net present value of \$438 million. Assuming that the syncrude is valued at a price similar to that of crude oil, a long term crude oil value of \$55/barrel (2007 dollars) would be necessary to obtain a 12% project ROI.

The analysis team defined five different cases that vary the amount of  $CO_2$  compressed after removal from the syngas and raw F-T product stream. The rationale behind these cases is to determine the impact on the plant performance and financial return if the decision is made to sequester some of the  $CO_2$  produced by the facility. The cases differed solely in the amount of  $CO_2$  compressed (0 to 90%), the export power (85.8 MW with no compression to 23.7 MW with 90% compression), and the plant EPC cost (savings of up to \$67.4MM if no compressors are installed). Since  $CO_2$  must be removed from the syngas and F-T product off-gas to prevent build-up in the F-T reactor, the cases have no difference in the depth of  $CO_2$  removal or the technologies employed. A schematic of the different cases considered and the impact on the amount of  $CO_2$  captured can be seen in Figure 2 below.

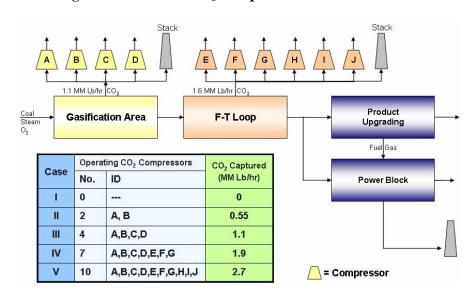


Figure 2 Alternate CO<sub>2</sub> Compression Cases Considered

The PSFM model entries for the base case are used as the starting point for this analysis. The base case is equivalent to "Case V", where 90% of the CO<sub>2</sub> is captured and compressed. To model the remaining cases, the EPC cost is decreased and export power increased as CO<sub>2</sub> compressors are removed from the design. The cost of transport and sequestration is NOT included in this initial analysis; later analysis includes an estimate for these costs when determining how federal policies could impact the decision of whether to sequester CO<sub>2</sub> from CTL plants or not. The results of the five cases can be seen in Figure 3 below:

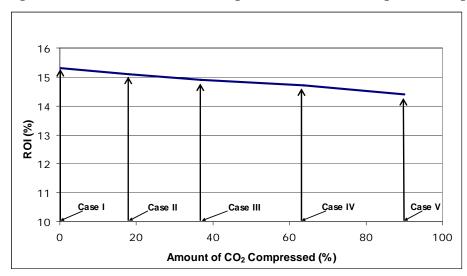


Figure 3 ROI Impact, Different Levels of CO<sub>2</sub> Compression Without Transport and Sequestration Costs

The result of this exercise shows that including additional compression to prepare the captured  $CO_2$  for geologic sequestration or other external use does not have a large impact on the plant ROI. The difference between all five cases is less than one percentage point. The cost savings gained by not including the  $CO_2$  compressors (\$67MM or ~2.4% of the total plant EPC cost) is small relative to the overall plant cost. While EPC cost is an important variable, a change of this magnitude is not enough to make a very large impact on the overall financial return. The other benefit to the plant financials by not compressing  $CO_2$ , a higher level of export power, also has little impact on the ROI. The revenue from export power is very small when compared to the income generated by syncrude sales. Even increasing the export power level by 62 MW (Case I relative to Case V) only increases yearly net revenue by 2.5%. This small increase provides little overall benefit to the ROI. Since the equipment necessary to remove  $CO_2$  from the syngas and F-T product streams is required regardless of whether  $CO_2$  will be sequestered or not, the incremental cost to the facility to prepare  $CO_2$  for pipeline transport is relatively small.

Given this small difference in ROI between capture with compression and capture without compression cases, it may seem that policies that put a price on CO<sub>2</sub> emissions will lead to many CTL plants including sequestration in their base designs. However, a more rigorous analysis that includes costs for CO<sub>2</sub> transport/sequestration and that estimates what the value of CO<sub>2</sub> could be under different policies must be performed to predict what CTL plants may do with better accuracy. The rest of this paper examines the major GHG policies that have been proposed in the US Senate (as of April 2007) and their potential impact on CTL plant designs.

## 2007 Federally Proposed GHG Control Policies

Recently introduced GHG policies vary considerably on the amount of GHG reduction required, the mechanisms allowed to achieve reductions, and the groups and industries impacted. The five policies shown below cover a wide range of GHG emissions targets and reduction mechanisms.

- 1) Climate Stewardship and Innovation Act of 2007, S.280 (Lieberman) The newest incarnation of the "McCain-Lieberman" proposal for GHG reductions, this is the most high profile bill, with 9 cosponsors, including 3 Republicans and high-profile Democrats (Senators Clinton and Obama). This proposal would have the EPA oversee a GHG cap-and-trade system, with targets set to reduce GHGs to 33% below 2000 levels by 2050. This is more aggressive than previous McCain-Lieberman proposals, where the target was 2050 emissions levels equaling those in 2000. Facilities that emit more than 10,000 metric tons of GHGs per year would be required to comply; this provision would include most large-scale CTL plants.
- 2) Global Warming Pollution Reduction Act of 2007, S.309 (Sanders) This bill is much more aggressive than McCain-Lieberman, mandating a reduction of GHG emissions to 1990 levels by 2020, and a reduction of 80% below 1990 levels by 2050. No cap-and-trade system is explicitly outlined, although it does grant the EPA authority to "establish market based programs". All power plants built after 2011 must not exceed the CO<sub>2</sub> emissions standard defined by a combined cycle natural gas plant, and all power plants in the country will be required to meet this standard by 2030. Beginning in 2015, power plants (25 MW or more) that use coal must meet a "Low Carbon Generation Requirement" that could require the capture and sequestration of CO<sub>2</sub>. The bill has 13 Democratic co-authors, but does not appear to have bipartisan support.
- 3) Electric Utility Cap and Trade Act of 2007, S.317 (Feinstein) Unlike the other bills mentioned thus far, this bill focuses solely on units exporting more than 25 MW of electric power. Targets for this bill are to cap GHG emissions at 2006 levels by 2011, and 2001 levels by 2015. The target in 2020 is to have emissions that are 25% below what would have occurred if no regulatory scheme was in place. The EPA will auction emissions credits, with money raised given to low-carbon technology research and ways to mitigate the impacts of climate change.
- 4) Global Warming Reduction Act of 2007, S.485 (Kerry) This is the other major GHG bill introduced in the 110<sup>th</sup> Congress with bipartisan support (Senator Snowe). The bill covers a wide range of sectors of the US economy, with policy measures impacting power plants, home appliance efficiency, land

- management, and vehicles. A cap-and-trade system would be applied to major sectors of US industry, with a goal of 1990 emissions levels by 2020, and 65% lower than 2000 levels by 2050.
- 5) GHG Intensity Targets with CO<sub>2</sub> Price "Safety Valve" (expected from Senator Bingaman and Specter, summer 2007) The Chairman of the Senate Committee on Energy and Natural Resources, Senator Bingaman of New Mexico, is expected put forth legislation that establishes a GHG cap and trade system with emission targets tied to GHG intensity (emissions per unit of GDP). A draft bill was recently analyzed by the DOE's Energy Information Agency (EIA, 2007) to determine the impact on US emissions. Under this bill, the US would set emissions allowances starting in 2012 that would reduce GHG intensity by 2.6% per year through 2021, and then increase to 3% through at least 2030. A CO<sub>2</sub> "safety valve", or maximum allowance price, would start at \$7/metric ton (nominal dollars), then increase by 5 percentage points over inflation per year.

## **Quantification of GHG Prices**

Until any one of these GHG control systems is put into place, it is difficult to predict the market value for GHG emissions. The detail of how the market mechanisms will behave and the level of credits allocated to each sector for the proposed policies remains to be worked out. CTL plants could be categorized as either a power plant or transportation fuel production facility; this could significantly impact their allocation and lead to advantages or disadvantages when compared with other technologies in the field.

The high carbon content of coal assures that any pending GHG regulation will impact the financial return and design of projects that use coal as a feedstock. Project developers must include potential costs and liability from  $CO_2$  emissions to determine their level of risk. This will help to determine if the project should include mechanisms to sequester  $CO_2$ , and what impact these mechanisms have on the project's bottom line.

Two different approaches are used to estimate the impact of GHG reduction policies on the CTL designs. Each involves estimating the price of  $CO_2$  emissions allowances under the assumption that a CTL plant would need to purchase allowances for up to 90% of the plant emissions. A range is considered under each approach to develop an understanding for how different price scenarios could impact the financial performance of CTL plants. The approaches used are:

- ➤ Method #1: Enter a range of flat CO₂ prices (indexed for inflation) for the life of each project. The range used is between \$5/ton and \$60/ton. The high end estimate is based on studies by Battelle (Dooley, 2006) projecting the cost driver necessary for most coal power plants near sequestration sites (within roughly 100 miles) to capture CO₂. A curve showing the return on investment for each plant under a range of CO₂ price scenarios shows what the value of CO₂ is that justifies CO₂ capture and storage.
- ➤ Method #2: Increase the CO₂ price every year to reflect tightening CO₂ restrictions proposed in many Congressional policies. This "ramp-up" strategy for CO₂ costs could give industry sufficient time to adapt their technologies to the new regulations. Two different cases are evaluated, roughly based on the price estimates projected to be necessary by Battelle to stabilize the atmospheric CO₂ concentrations at 450 and 550 ppm. Some currently proposed Congressional policies use these targets as goals to mitigate climate change impacts; for example, Kerry-Snowe is close to the 550 ppm goal, while Sanders-Boxer most closely matches the emissions trajectory needed to meet a 450 ppm stabilization target (Kant, 2007). The prices for each case can be seen in Table 3.

Table 3 Estimated CO<sub>2</sub> Prices to Meet Atmospheric Stabilization Goals

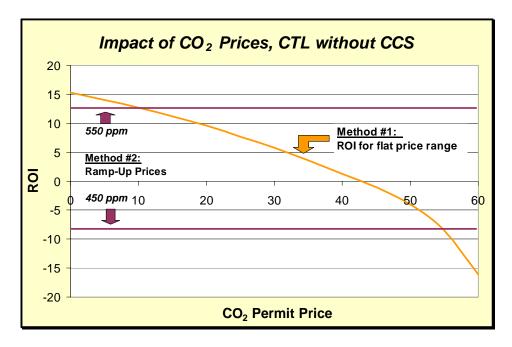
	CO <sub>2</sub> Price (\$/ton)	
	Stabilization Target	
	450 ppm	550 ppm
Year		
2010	10	0
2015	20	5
2020	30	10
2025	40	15
2030	50	20
2035	60	25
2040	70	30

Since the CTL plant designs outlined earlier do not include a cost for transport and storage, a factor of \$10/ton is added to the operating cost of the plant to reflect additional sequestration costs. The different CO<sub>2</sub> prices are entered into the PSFM as a cost for the cases both with and without compression of CO<sub>2</sub>. The result of this analysis demonstrates the scenarios where capture and storage of CO<sub>2</sub> in a CTL design could be economically justified.

#### **Results of Financial Analysis for GHG Control Scenarios**

The financial analysis performed for "Case I" outlined in Figures 2 and 3 represents the return possible for a CTL design without compression and sequestration where CO<sub>2</sub> has a \$0/ton value. Once a value for CO<sub>2</sub> is included into the financial model, a picture develops for how GHG control policies may impact the plant's ROI. Figure 4 below shows the ROI for a CTL plant without sequestration using the different CO<sub>2</sub> pricing methodologies.

Figure 4 CTL Plant ROI Without CO<sub>2</sub> Sequestration, Different CO<sub>2</sub> Pricing Scenarios



A very wide range of possible financial outcomes are possible depending on the CO<sub>2</sub> price. The results using a flat CO<sub>2</sub> pricing methodology (Method #1) shows that prices must be over \$40/ton for the plant ROI to become negative. The benchmark for determining if a plant will be built is not where ROI is zero, but rather where ROI hits the minimum value desired by equity investors. For a plant of this size and risk profile, a return of 12% or

more would likely be demanded; it would not take a very high CO<sub>2</sub> price (only \$12.50/ton) for ROIs to dip below 12%.

Using a "ramp-up" of CO<sub>2</sub> prices as performed in Method #2 shows very different results depending on which CO<sub>2</sub> stabilization concentration is set as the goal. The price impacts in the 550 ppm case are relatively small, reducing ROI 2.5 percentage points to 12.8%. The CO<sub>2</sub> price in the 450 ppm case impacts the plant financials much more significantly, dropping ROI to -8.2%. Policies that attempt to reach a 450 ppm stabilization goal would almost certainly require that any CTL plants built include equipment for carbon sequestration.

The ROI shown in Figure 3 for Case V represents the impact of including compression in the CTL design. Once the \$10/ton cost for transport and storage is included, the ROI of this design falls to 12.0%. Since this plant would not be required to purchase any emissions credits, the ROI remains constant no matter what the CO<sub>2</sub> permit price is in a credit-purchase scenario. This case is break-even with Case I (no compression) at a flat CO<sub>2</sub> price of \$12.50/ton. The financial result is similar to the ROI in the 550 ppm scenario case without sequestration (12.8%), and far superior to the 450 ppm case without sequestration (-8.2%). Policies reflecting a 450 ppm CO<sub>2</sub> target would likely lead to CTL plants with sequestration, while 550 ppm targets do not provide a strong economic driver to promote sequestration in CTL facilities built early next decade.

All of the financial analysis done to this point assumes that CO<sub>2</sub> credits must be purchased and that an adequate supply of permits is available. This may not be the case in many GHG reduction policies; cap-and-trade systems with gradual reductions in the cap level may lead to credit shortages. In addition, some policies may give-away some or all permits for free, allowing credit holders to emit at no cost or sell the credits if they possess more than they need. Either of these cases may lead to a scenario where a CTL plant with sequestration may possess credits that could be sold on the open market. Because CTL plants have a relatively low cost of CO<sub>2</sub> sequestration for a fossil fuel facility (\$12.50/ton, compared with ~\$25/ton for IGCC plants and ~\$50/ton for PC plants), they may be able to sell many of their emissions credits at a profit. For the Case V design with sequestration, Figure 5 shows the plant ROI at different CO<sub>2</sub> credit levels.

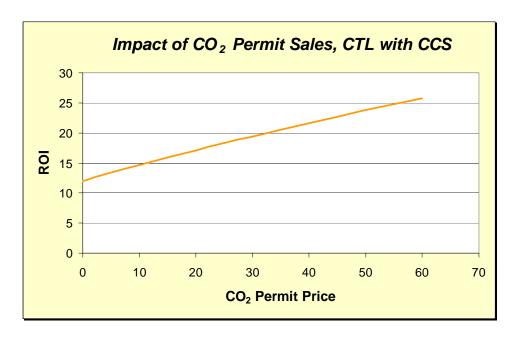


Figure 5 CTL Plant ROI With CO<sub>2</sub> Sequestration and Emissions Permit Sales

Based on the financial analysis performed for the CTL designs under different CO<sub>2</sub> pricing scenarios, estimates can be made for how each federal GHG reduction policy may impact CTL plant GHG emission strategies. Only the Sanders-Boxer bill provides a clear driver for CTL plants to sequester CO<sub>2</sub>. Policies targeting 550 ppm stabilization, such as Kerry-Snowe and McCain-Lieberman, do not give CTL project developers adequate incentives. A summary of each bill and its likelihood to promote CTL with CCS can be seen below.

Table 4 Likely Impact of Federal GHG Policies on CTL CCS Decision

Bill	CTL with CCS?	Comments
McCain-Lieberman (S.280)	Break-even, no major driver	Although above 550 ppm case by 2040, "step- change" could require early action
Sanders-Boxer (S.309)	Likely	ROI without CCS ~5%; provisions may mandate CCS in coal plants
Feinstein-Carper (S.317)	Not applicable	Power sector only, unclear if would require CTL plants to comply
Kerry-Snowe (S.485)	Break-even, no major driver	Results similar to 550 ppm case (12.8% vs. 12.0% ROI)
Bingaman-Specter (forthcoming, summer 2007)	Unlikely	ROI without CCS = 13.3%; incentives not great enough to push CTL CCS

For CTL plants that are to be built in the next decade,  $CO_2$  costs must be relatively high to incentivize the sequestration of  $CO_2$ . Of the policies outlined above, Bingaman-Specter would likely lead to the lowest market value for  $CO_2$ . This policy is tied to carbon "intensity" and is not working toward a reduction in the absolute amount of  $CO_2$  emitted through 2050. The "safety valve" included in this bill will keep the  $CO_2$  price under \$14/ton throughout the life of the CTL plant, leading to a ROI without sequestration of 13.3%. Since this is above the 12.0% ROI projected for the CTL plant with sequestration, it is unlikely that this policy alone would be a sufficient driver for sequestration.

Even policies that work toward net emission reductions, such as the McCain-Lieberman and Kerry-Snowe bills, may not provide sufficient drivers toward sequestration. Both of these policies promote emissions reduction trajectories that are similar to the 550 ppm stabilization pathway. By 2040, the Kerry-Snowe bill will likely right on target, while McCain-Lieberman will be somewhat above. However, since McCain-Lieberman requires aggressive "step-changes" in emission reduction during the first 20 years, the trajectory can be considered a rough proxy for the 550 ppm target. As shown in Figure 4, the CO<sub>2</sub> prices that reflect the 550 ppm stabilization target gives the no sequestration case a financial return that is close to break-even with the sequestration case (12.8% vs. 12.0%). For a CTL plant with an expected start-up date of 2011, the likely CO<sub>2</sub> prices under these policies are too low during the majority of the plant life to provide a major capture driver. CTL plants with much later start-up dates that face higher CO<sub>2</sub> prices may not find this to be true.

The emissions trajectory of the Sanders-Boxer bill leads to  $CO_2$  prices that result in a ~5% ROI for the case without sequestration. This provides a clear signal to project developers to include sequestration in near-term CTL designs.  $CO_2$  prices under this policy are high enough during the beginning of the plant life to drive this design decision from the project outset. In addition, this bill provides additional language that could require that coal plants sequester  $CO_2$  due to the "Low-Carbon Generation Requirement" and "Emissions Standards for Electric Generation Units" clauses.

#### **Conclusions**

When compared to coal plants that generate power only, the net cost of carbon sequestration for CTL plants is low. CTL plants must capture CO<sub>2</sub> due to F-T reactor requirements, making the marginal cost of sequestration from compression, transport, and storage only. Based on the CTL plant design considered during this analysis, this additional cost is estimated to be \$12.50/ton CO<sub>2</sub>. GHG reduction policies that provide an economic driver at this level or greater will provide enough incentive for CTL project developers to strongly consider carbon sequestration in their designs. The relatively low cost of sequestration when compared to other fossil fuel

facilities may lead CTL plants to sequester CO<sub>2</sub> and sell emissions credits, providing the plant with an additional revenue stream.

Four of the five US Senate GHG emissions reduction policies evaluated did not provide a clear incentive for the CTL plant evaluated to sequester CO<sub>2</sub>. The imposed carbon prices during most of the plant life are not high enough for a CTL plant starting-up in 2011 to change operations. The one policy that does bring about a change in behavior, Sanders-Boxer, provides a relatively high initial CO<sub>2</sub> price that is ramped-up throughout the CTL project life. Due to little bipartisan support for Sanders-Boxer, it is unlikely that a bill of this nature would become law in 2007.

Future analysis by Nexant and NETL will examine not only GHG policies that impact CTL plants, but other federal and state programs that incentivize or restrict this emerging commercial technology. The GHG analysis performed here may also be expanded to include other clean fossil technologies and specific facility analysis.

## Acknowledgements

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